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The effects of sunscreen use and window glass on daylight photodynamic therapy dosimetry

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Daylight photodynamic therapy (dPDT) is a widely used treatment in the management of field-change actinic keratoses (AK).[1] Daylight PDT relies on natural daylight activating photosensitisers (typically protoporphyrin-IX, PpIX) in diseased tissue to initiate PDT effects. During the delivery of dPDT, it is recommended that a minimum PpIX-effective light dose is delivered to the treatment site.[2] PpIX-effective light dose is the product of the spectral irradiance of the light source and the normalised PpIX absorption spectrum, integrated over the treatment duration. The current European guidelines suggest a minimum PpIX-effective dose of 8 J cm^{-2}, though other research suggests that this may be lower.[3–5] Daylight PDT may be undertaken using daylight through window glass in situations where there is ample daylight, but the outdoor conditions are unfavourable.

Standard practice in dPDT involves application of a high SPF sunscreen on all exposed sites prior to pro-drug application and subsequent sun exposure. It is recommended that organic (chemical) sunscreens are used, which filter only the ultraviolet (UV) part of the spectrum.[1] However, the absorption spectrum of

PpIX extends into the UVA (<400 nm), and therefore some sunscreens may attenuate light that might otherwise activate PpIX. This means that in published literature the reported dose may be higher than the actual dose delivered to the skin, depending upon the sunscreen used.

We would like to initiate discussion, considering the following. A spectral irradiance measurement is taken in clear skies (13:00 GMT 14/05/14, Chilton, UK). This measurement is weighted for PpIX absorption, and then weighted for either the transmission spectra of double-glazed window glass or one of several commercial sunscreens (Figure 1, sunscreen transmission measured with Labsphere UV1000 (Labsphere, New Hampshire), 2 mg cm^{-2} density on Transpore tape and quartz slide).[6] The resultant PpIX-weighted dose values are compared for a 2 or 2.5-hour treatment duration in dPDT and conservatory-based dPDT respectively.

The reduction in PpIX-weighted dose through different sunscreens varied, between a 38% and 92% reduction, while through window glass the PpIX dose was reduced by 22%. All sunscreens measured have some visible light attenuation (>400 nm), and critically at the 408 nm absorption peak of PpIX.[7] One of the first published studies on dPDT compared the PpIX and P20 SPF20 (Riemann A/S, Denmark) absorption spectra, which at the time had a formulation with significant UVA transmission.[2] However, the formulation has updated in the intervening years to attenuate more UVA resulting in a theoretically lower PpIX dose. Additionally, Actinica® (Galderma, Switzerland), one of the most commonly used sunscreens in dPDT, absorbed heavily in the UVA and reduced the PpIX dose to 35% of the unfiltered dose. This may explain, in part, our own experience with dPDT, which has tended to show lower efficacy rates than those in published studies following single dPDT treatments.[8] UVA and visible light attenuation by sunscreens may in part explain this difference, with particular relevance at more northerly latitudes with less daylight and thus more likely to deliver below the minimum dose threshold.

A reduction in dose is also seen for conservatory-based dPDT, which is accounted for with longer recommended treatment times, but there remains a lower reduction in dose compared with sunscreens.

Our results highlight the large differences in PpIX-effective dose depending on the sunscreen used and, therefore, careful consideration of the choice of sunscreen is important. Ideally the spectral transmission of the sunscreen should be known; our results show that simply relying on organic sunscreens may not be

adequate (from Figure 1, 5 of 9 sunscreens contain only organic filters). In our clinic, sunscreen is applied by trained nurses, however with variation in application and considering self-administered dPDT, higher doses to the skin may result than presented here. Previous published literature has not always considered the absorption of different sunscreens and their impact on PpIX-effective dose and therefore it may be that simple comparisons between studies are not always applicable. Daylight PDT is still an effective treatment however, perhaps due to centres typically performing dPDT in favourable weather conditions, therefore avoiding the minimum dose by delivering high doses of light.

Daylight PDT continues to evolve, and with more diverse methodology comes a need for more detailed understanding of dosimetry. It is important that the dosimetry underlying effective dPDT is detailed in order to provide confidence to practitioners that effective doses are delivered. Awareness that both sunscreen choice and use, and window glass reduce the effective dose of light delivery by a variable, yet significant amount is helpful in determining dose regimes to compensate and avoid potential loss of efficacy.

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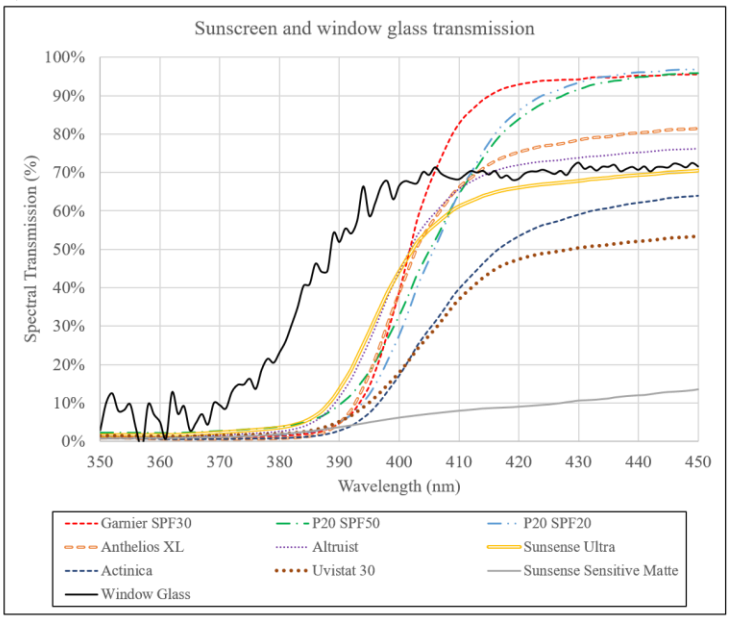
a)



b)

	Composition	PpIX Dose ± SD (J cm^{-2})	Reduction (%)
Daylight	N/A	15.91	
Garnier Clear Protect	SPF30, O	9.81 (0.14)	38%
P20 SPF50	SPF50, O	8.84 (0.10)	44%
P20 SPF20	SPF20, O	8.72 (0.16)	45%
Anthelios XL	SPF50+, O	8.25 (0.26)	48%
Altruist	SPF50, I, O	8.22 (0.48)	48%
Sunsense Ultra	SPF50+, I, O	7.76 (0.36)	51%
Actinica	SPF50+, O	5.51 (0.08)	65%
Uvistat 30	SPF30, I, O	4.97 (0.14)	69%
Sunsense Sensitive Matte	SPF50+, I	1.22 (0.13)	92%
Window Glass	N/A	12.54	22%

Figure 1. a) Sunscreen and window glass spectral transmission data. Sunscreen transmission data only available up to 450 nm, transmission above 450 nm assumed to be spectrally flat. Sunscreens categorised by labelled SPF rating, and whether they contain organic (O) and/or inorganic (I) filters. b) PpIX dose (± standard deviation) is calculated for each sunscreen transmission (mean for five transmission measurements on each sample) and through window glass for a representative daylight spectrum (350-800 nm) and treatment duration, and the resultant percentage reduction in dose is displayed.